

Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
Professor name: Prof. Amitabha Bhattacharya
Department name: Electronics and Electrical Communication Engineering
Institute name: IIT Kharagpur
Week :11
Lecture 55: Grounding

Welcome to the lecture of the course on EMI EMC and Signal Integrity Principles, Techniques and Applications. Now, in the last class we have discussed about shielding, today we will be discussing about grounding another very important aspect of EMC. So, what is grounding? Grounding is the process of electrically connecting conducting objects to the earth. So, earth will get additionally charged due to that in order to minimize the potential difference between them because if that potential difference is very high between an object and the ground then there may be electrostatic breakdown etcetera electrical breakdown of air media. So, to minimize that this is done.

WHAT IS GROUNDING ?

- Grounding is the process of electrically connecting conductive objects to the earth (which may get charged) in order to minimize the potential difference between them.

Now, again why we ground as I said that it gives safety of equipments and personals against if there is any fault in the circuit. Protection against transient we have seen lightning may come we have seen various ESD effects. So, if they come how to protect the way is those additional charges that come from this lightning ESD etcetera for a very short time. So, that to create a path so that the potential is minimized. Then EMI control various interference to direct them to the ground then fire protection and functional ground because various devices or various components will not work if they are not properly grounded you know any electronic equipment that needs a certain voltage. Now, with respect to functional ground that is done suppose a TTL logic that would not

operate if you give a certain voltage. So, 2.5 volt there now if that 2.5 volt is not proper then the circuit would not come. So, this is come under functional thing and fire protection that is if due to that high voltage any electrical breakdown is there then there will be fire etcetera. So, to prevent that also is grounding is done.

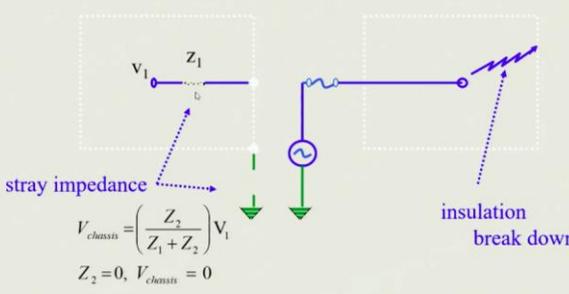
WHY GROUNDING ?

- Safety of equipments & personnel against faults
- Protection against transients (lightning, ESD, etc.)
- EMI Control
- Fire protection & functional ground



Now, this is safety ground you see that in the left there is that always there is some stray impedance is there either mainly capacitance type of thing or if in the right side the picture shows that if there is the air insulation breakdown then there will be an wave generated and so there will be some energy here coming dissipated. So, that energy so all these can be modeled as there is a voltage developed due to all these. So, safety considerations require chassis or enclosures for electronic equipment to be grounded otherwise it may reach a dangerous voltage level through stray impedance or insulation breakdown. Stray impedance you know always comes because there are if there are any gaps created somewhere there will be a stray capacitance type of thing either capacitance or at some frequency that may also act as an inductance.

SAFETY GROUND ?

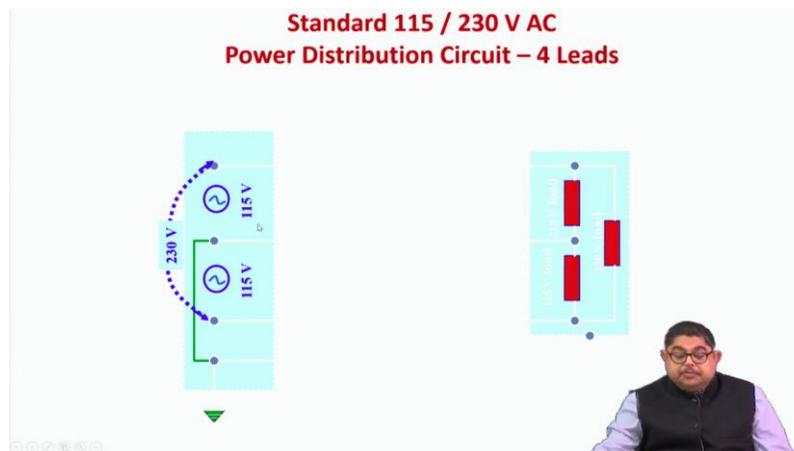
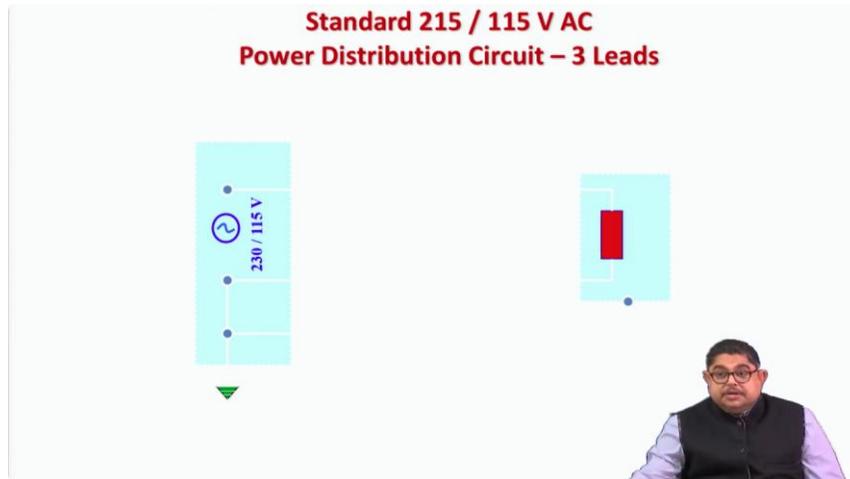


$$V_{chassis} = \left(\frac{Z_2}{Z_1 + Z_2} \right) V_1$$

$$Z_2 = 0, V_{chassis} = 0$$

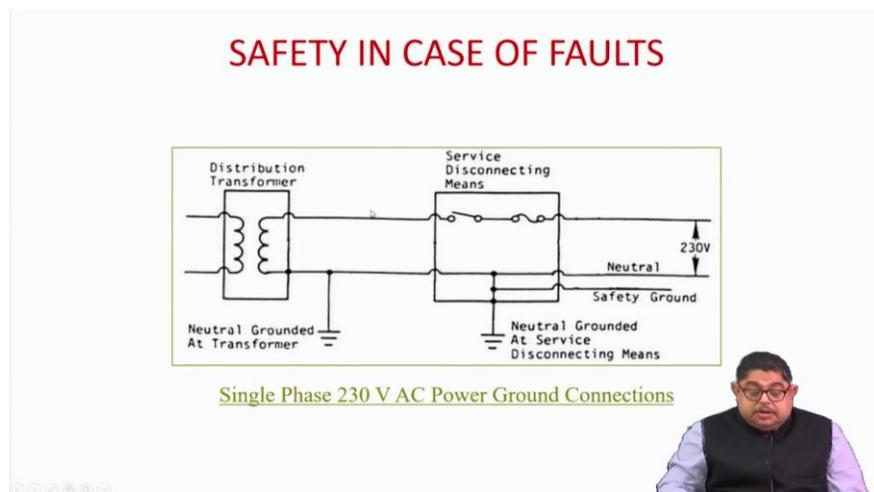
Safety considerations require chassis or enclosures for electric equipment to be grounded, otherwise, it may reach a dangerous voltage level through stray impedance or insulation break down

Now, this is the power distribution circuit 215 volt or in a 115 volt AC here you see this is a 3 leads distribution circuit. So, you take 3 phase from it phase neutral and ground. Now, also the better circuits are 4 leads. So, you take between these 2 ends here it is called 115 because in USA they use 115 in our country we use 230 volt. So, between the other 2 you will get 230 volt between these 2 you will get 230 volt. So, 230 volts you are getting here which is not possible in a 3 lead circuit.



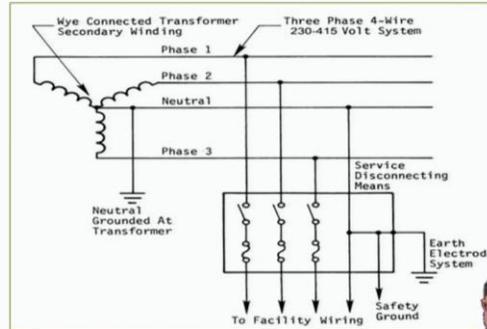
Now, you see there is always a distribution transformer because we always use a transformer to isolate the power distribution side to giving any power. So, in the houses it is not there, but in a distribution network. So, nearby that is always some distribution

transformer and its neutral is grounded at the transformer. Now, this is your service side. So, there are service disconnecting mains there is a fuse here also the neutral is grounded at service disconnecting thing also there is a safety ground. So, all these points are grounded, grounded means you need to physically ground it. So, for that you need to go down we will come at the end of this lecture or the next lecture that you will have to make a ground connection there ground means you go deep inside earth. That means you will have to dig a hole there you go to ground and then there you put some coal etcetera and you measure that the resistance is very low. So, because always there will be some state resistance earth has a lot of charges, but you try to make there that it is coming to your very low resistance generally 4 degree 5 degree resistance. So, this point is grounded like that this is grounded now also you take a safety ground and do that. So, all these are done. So, that if there is any fault anywhere and that comes. So, that huge charge that time huge current that gets a path to go. So, all these paths are then created.



So, this is for this is a transformer. So, phase 1 phase 2 phase 3 and neutral. So, neutral is grounded at transformer same like previous case only this is a 3 phase circuit. So, service disconnecting means again the same thing also here there is a safety ground. So, whatever I was talking is this earth electrode system. So, from there a safety ground there is ground is also created and then it goes to this facility wiring whatever you have you get in your homes residence etcetera that is this wiring.

SAFETY IN CASE OF FAULTS



Three Phase 230/415 V AC Power Ground Connection

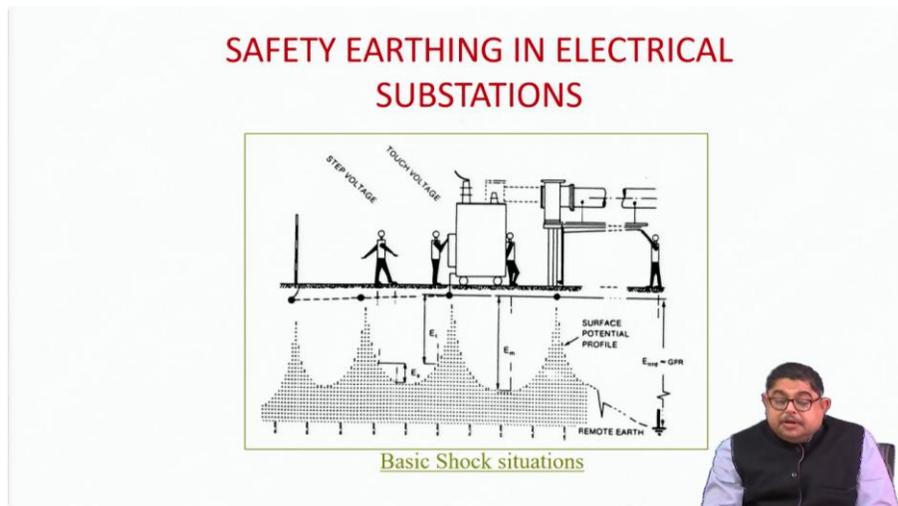
Now, you know that if there is a fault you will get at some point some shocks there is an idea that how much current is flown there. So, from power line either 50 or 60 hertz in our country it is 50 hertz. So, milli ampere how much current is flown for AC up to 1 milli ampere current the you will understand that there is some problem, but it is not you will dangerous. Similarly, for direct current the it is a bit high actually this alternating current means these are RMS values the peak values actually matter. So, that is why in DC it is a higher value. So, up to 4 milli ampere it is like that there is a shock. Now, from up to 3 milli ampere AC you will just take your hand out and up to 21 milli ampere you will be getting good shock, but actually there is not much dangerous things with that. So, those who work with electric things electricians etcetera for them up to 20 milli ampere is 21 milli ampere, but after that you see it gives you muscular inhibition and then there is a if you increase more that shock it will be respiratory block you would not be able to take any respiration and above 100 it is typically a fatal for human beings.

SAFETY IN CASE OF FAULTS

- Summary of the effect of shock

Alternating Current {50/60 Hz} (mA)	Direct Currents (mA)	Effects
0.5 – 1	0 – 4	Perception
1 – 3	4 – 15	Surprise (Reaction Current)
3 – 21	15 – 80	Let Go Current
21 – 40	80 – 160	Muscular Inhibition
40 – 100	160 – 300	Respiratory Block
Over 100	Over 300	Usually Fatal

So, this is the case of safety are being in electrical substations in electrical substations from the power stations power generating stations the thing comes and there it gets distributed then it goes to our distribution network. So, there you see that though the it is grounded the surface potential profile is something like this. So, there are points where the profile has a minima where the profile has a maxima based on that there are some points where only you can stand. So, you see these personals are doing they are on a particular point where the profile has been measured they are avoiding the high surface voltages and there are markings there. So, they understand that where to stand and work because they will have to work. So, with the those high voltage things.



Now, transient protection we have said earlier also that transient means lightning ESD this type of thing. So, protection against lightning transient we have another slide will show you use of shielding wire over the power line conductor. Usually the power line conductors are not shielded it is not possible because it will increase the cost enormously otherwise if it can be done it is good, but till now human civilization has not gone to that level that we have so much money to know advanced countries also they do the shielding, but at least the ground where if it can be shielded that is good for lightning and lowering the tower footing resistance by using ground rods or some counter poised wires these are the lightning actually lightning is a severe phenomenon you see every year many deaths occur due to this, but so if lightning can be prevented particularly in high value installation sites this is a challenge this is an active area of research also that how to protect how to design lightning arrestors how to ground the lightning towers etcetera.

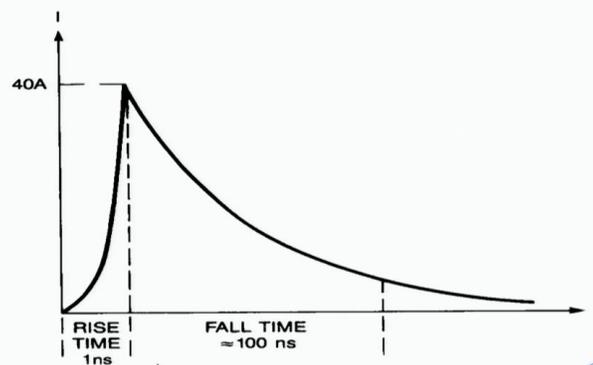
TRANSIENT PROTECTION BY GROUNDING

- Transients
 - Lightning
 - ESD
- Protection against Lightning transient
 - Use of shielding (ground) wire over the power line conductors
 - Lowering the tower footing resistance by using
 - driven ground rods
 - counter poise wires



This is the ESD waveform I think we have seen this when we have discussed the electromagnetic environment so this is you see a typically ESD waveform it goes up to 40 ampere you see quite high value, but it is rise time is 1 nanosecond. So, within very short time is goes then is decays with a fall time of 100 nanosecond and then it comes to very low value. So, for a very short time you get a very high current that is typical of ESD electrostatic discharge.

PROTECTION AGAINST ESD



So, protection against it provision of good DC return path to earth use of guard trace in PCBs that means just the trace it will its job is one point should be properly grounded. So, that not the functional ground not the digital ground it is properly grounded and increase the immunity of electronic components. So, components also they can be bought so you will have to give extra money for buying capacitors inductors etcetera which are ESD immune so you can use that one.

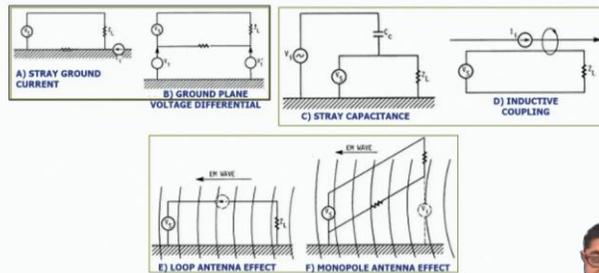
PROTECTION AGAINST ESD

- Provision of good dc return path to earth
- Use of guard trace (single point grounded) with PCBs
- Increase immunity of electronic components



EMI control by grounding so you see that various coupling modes one is the first one is my first one is stray ground current. So, you see that a stray current is flowing here so there will be this part is the common mode current so resistance due to that so that will be so this will induce some coupling current. So, this is ground plane voltage differential there you have one is V_s and other there will be some V_s dash etcetera. So, there will be a coupling voltage this is the again common mode resistance stray capacitance you see there is a stray capacitance in the path. So, you will that also gives you coupling this is inductive coupling so from another wire is carrying current nearby your circuit. So, that will induce some coupling then loop antenna effect that means a magnetic dipole so that will radiate and that will induce some current. Similarly, you can have a monopole which is a electric source so there also you will obviously get electromagnetic wave so by that also you will get coupling.

EMI CONTROL BY GROUNDING



Summary of Coupling Modes



Again we now come back to the ground so sometimes the ground is defined like this an equipotential point or plane that serves as a reference potential for circuit or system, but this definition is not representative of practical ground system because practical ground systems are not equipotential as I said that grounding there will be some potential small potential and they are not equipotential all the grounds are not same your one systems ground is different from another system ground. Also it does not specify the actual path taken by the current in return to the source because that is important that what is the how the current is coming back to the source.

SIGNAL GROUNDS

- A ground is normally defined as :-
“An equipotential point or plane that serves as a reference potential for circuit or system.”

Note:

This definition is not representative of practical ground systems because they are not equipotential, also it does not specify the actual path taken by the current in return to the source

So, a better definition is a signal ground is a low impedance path for the current to return to the source. So, this is a new definition given by Ott in 79 so here you see the two drawbacks of the earlier definition are removed equipotential concept came and current coming back actually going to ground means it is coming back to the source because

source has also ground. So, when it went to the circuit or to load it came back via ground so that concept is there that it is a low impedance path for the current to return to the source.

SIGNAL GROUNDS (cont/-)

- A better definition :-

"A signal ground is a low impedance path for the current to return to the source (H. Ott 1979)

Note:

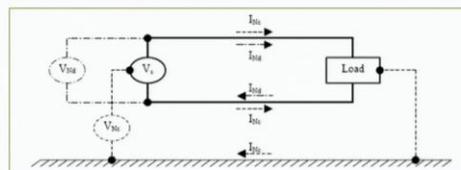
- **Equipotential concept defines**
- **Current concept defines**



So, this we discussed previously just for completeness sake I am putting it that when we discussed radiated emission and radiated emission that time we discussed what is differential mode current, what is common mode current, which one is dangerous etcetera.

MODES OF NOISE CURRENT FLOW

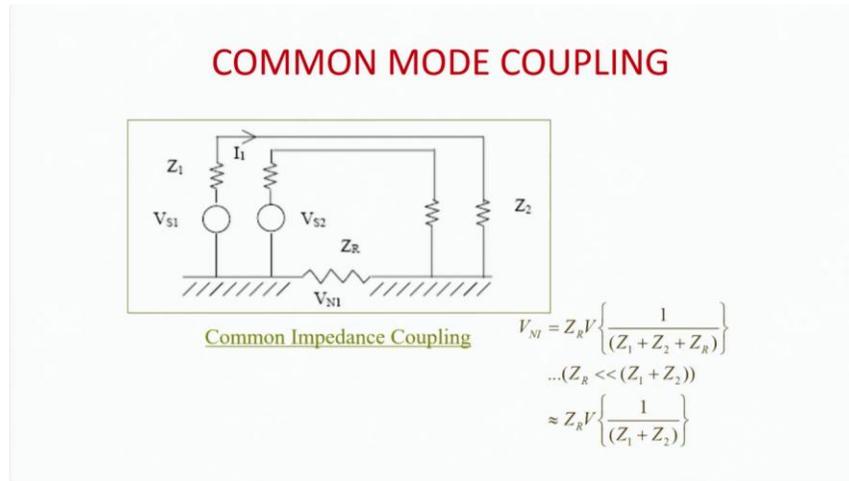
- Differential Mode (DM)
- Common Mode (CM)



Differential Mode and Common Mode Noise



So, this slide just that this is the common mode coupling we have seen all these concepts before techniques to reduce the coupling that time we said that increase physical separation improve the shielding ground plane impedance minimization. And this last one we have not discussed opening the ground loops by some means because if in ground there is a loop created so the common mode current that will flow through that loop and that will disturb.



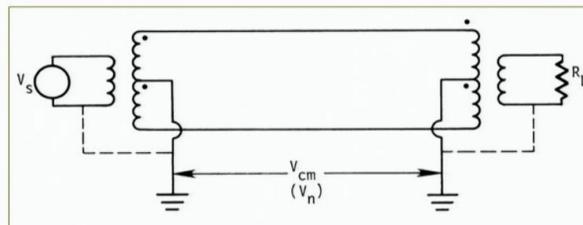
- ### TECHNIQUES TO REDUCE THE COUPLING
- Increased physical separation
 - Improved shielding
 - Ground plane impedance minimization
 - Opening the ground loops by some means

So, means to pin the ground loop this is single point grounding so you have a balanced transformer instead of an unbalanced transformer at both the ends both the source end and the load end. Now, that you we have seen that any balance thing the common mode is same there so when they are subtracted the common mode gets eliminated. So, always use balanced transformers in the two ends of the circuit. So, the same thing that is the common mode rejection so you see that whatever common mode was present actually

this I_{n1} and I_{n2} , but we know for common mode they are basically same, but to show that they are from two different paths it is shown like this actually I_{n1} is equal to I_{n2} . And so after this balanced transformer you see they are getting eliminated and we are getting only I_s .

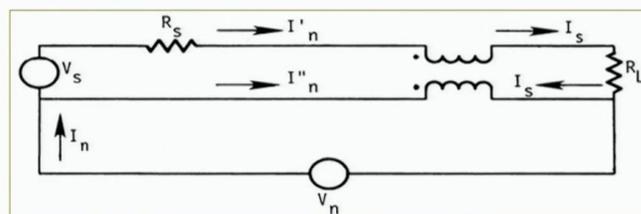
MEANS TO OPEN THE GROUND LOOPS

- Single point grounding
- Common mode rejection



Balanced Operation with Balanced-to-Unbalanced Transformers

COMMON MODE REJECTION



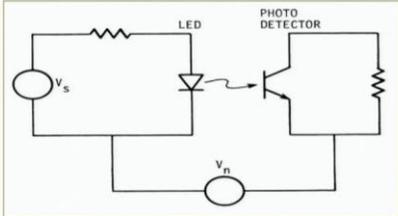
Common Mode Chokes



So, another way of opening the ground loop is you put in LED and that LED will again radiate you collect it through a transistor and pass it to the load resistor. So, by that you see if there was any common mode current that would not be able to come to the load. Similarly, so that means there is an optical isolation here also if required you can do a frequency translation because this LED you can properly select so that the actual frequency will get change there. So, all this will eliminate your common mode noise or interference

MEANS TO OPEN THE GROUND LOOPS (contd.)

- Frequency translation
- Optical isolation

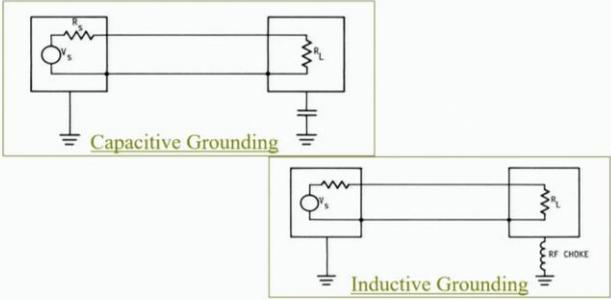


Use of Optical Isolation to Combat Common-Mode Noise

means to frequency selective grounding. So, you can have a capacitor attached this capacitor attached with this ground. So, this is called capacitive grounding. So, particular noises particular frequency interferences that will be eliminated by that similarly you can put inductor that those are called RF chokes. So, those RF noises you can eliminate the low frequency noise does not matter most of the time. So, inductive grounding also you can do. So, I think that is all about the first part of this course actually we have seen this various ways of doing grounding. Now, in the next class we will see some more aspects of grounding. Thank you.

MEANS TO OPEN THE GROUND LOOPS (contd.)

- Frequency selective grounding



Capacitive Grounding

Inductive Grounding